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Small and Large-Diameter, Water-Table Observation Wells Compared

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SHALLOW ground-water investigations usually involve the use of various sizes of perforated observation wells and/or sometimes batteries of piezometer tubes. Such equipment is used to determine the position of the water table, defined as the upper surface of the saturation zone and also the surface of atmospheric pressure (3, 4)^o. The zone of saturation, however, often extends above the surface of atmospheric pressure a distance dependent primarily on the soil texture.

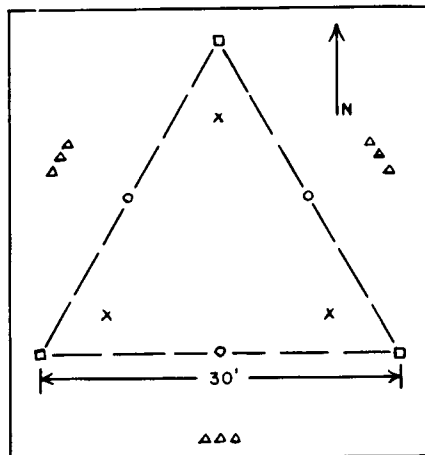
Observation wells may be cased with perforated pipe and gravel packed, or uncased, and large or small in diameter. An uncased observation well normally can be expected to reflect position of the water table more accurately than a cased well because of a greater seepage area from soil into the well cavity. Cased wells, however, are necessary in many instances, particularly where soils are unstable. The size of observation wells is often determined by factors other than those which would give the most reliable estimate of the water table. For example, observation wells sometimes are the holes remaining from soil characterization studies.

In a Michigan experiment, Hore and Kidder (1) found that water levels in small, perforated cased wells lagged behind those in larger diameter wells. They used 2-in. and 3/8-in. diameter wells in their study.

This paper summarizes the results of a study to determine the sensitivity of 4-in. and 3/8-in. diameter cased observation wells to water-table fluctuations in a fine-textured soil, and to evaluate the economics of installation.

Materials and Procedure

A field experiment was conducted in 1960, on a lacustrine silt loam having high organic matter content in the surface layers. The experimental site (Fig. 1) was on land having a good stand of



LEGEND:
 □ 4" Diameter Observation Wells
 ○ 3/8" Diameter Observation Wells
 △ 3/8" Diameter Piezometers
 X Tensiometer Batteries

FIG. 1 Field layout of observation-well comparison experiment.

bromegrass and alfalfa. Installations included three 3/8-in. and three 4-in. diameter observation wells; three sets of tensiometers with the porous cups at depths of 1, 3, 5, 6, 7, and 8 ft, and three sets of 3/8-in. diameter piezometers at depths of 10, 30, and 50 ft. Observation wells were installed to a depth of 12 ft. The 3/8-in. diameter well casings were galvanized steel pipe (inside diameter, 0.493 in.) with two opposing 3/32-in. perforations at 4-in. vertical intervals. These wells were installed by jetting a hole with 3/4-in. pipe, then inserting the 3/8-in. perforated casing (2). Casings in the 4-in. wells consisted of 4-in. inside diameter coal-tar-impregnated fiber pipe with three rows of 3/8-in. perforations (4 in. apart) at 90, 135, and 135 deg, respectively, from one another on the pipe periphery. The 4-in. casings were

placed in 6-in. holes which had been bored with a motor-driven drilling machine. The annular space around all observation wells was packed with sand and gravel to within two feet from the ground surface.

Readings from the small-diameter wells and piezometers were taken by blowing through a graduated plastic tube as it was lowered into the pipe casing. The water level was indicated by a bubbling sound. Water levels in the 4-in. wells were measured with a steel tape. After periods of high rainfall, readings from all instruments were taken more frequently than the normal twice-weekly readings.

Tensiometers were of the direct-reading (centimeters of water) mercury type, which were read each time the water levels were taken. A weighing recording rain gage was located about 250 ft from the experimental site. Hydraulic conductivity of soil was obtained by the piezometer method described in USDA Handbook 60 using steel electrical conduit 1 in. in diameter (4).

Results and Discussion

Descriptions of the soil profile horizons, textures, and *in situ* hydraulic conductivities are presented in Table 1. Soil textures were determined by "feel" and ranged from silt to silty clay. A silt layer 2 ft thick, was located at the 2.5 to 4.5-ft depth. Above and below the silt layer were less permeable layers of silty clay loam and silty clay. During the entire course of the experiment the water table was in the silt loam to silty clay loam horizons (Fig. 2).

Hydraulic conductivities were evaluated only at the 6 to 9-ft depths, near each 4-in. observation well. Rates at this depth ranged from 0.09 to 0.12 in. per hour. Hydraulic conductivities

TABLE 1. SOIL PROFILE HORIZONS, TEXTURES, AND *IN SITU* HYDRAULIC CONDUCTIVITIES

Depth, ft	Horizon	Texture	Hydraulic conductivity	
			At depth, ft.	Rate, iph
0-1	A _{1p}	Silt loam		
1-1.5	A ₁	Silty clay loam		
1.5-2.5	C _{ca}	Silty clay loam		
2.5-4.5	C ₁	Silt		
4.5-7	C _{2g}	Silt loam to silty clay loam	6-7	0.12 ^o
7-9	G	Silty clay loam	7.33-9	0.09 ^o
9-12	G	Silty clay loam to silty clay		

^o Average of three locations.

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^o Number in parentheses refer to the appended references.

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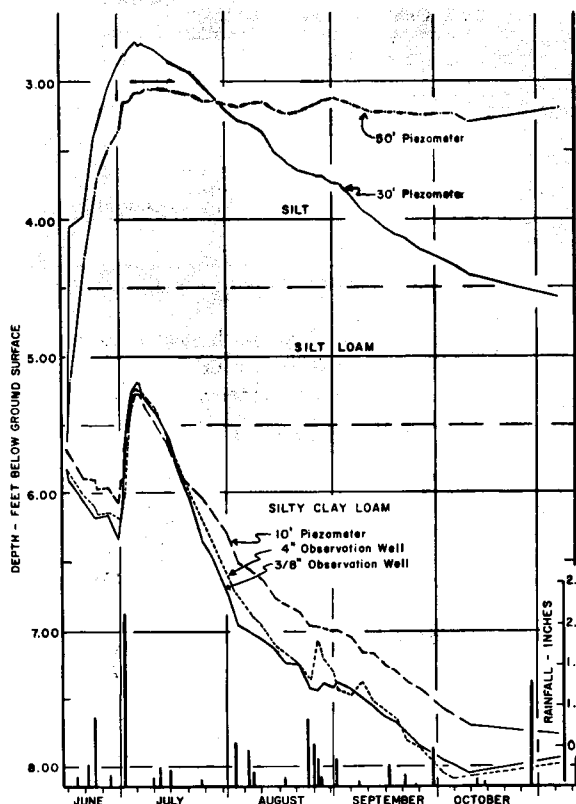


FIG. 2 Observation well and piezometer water levels (average of three installations) in 1960.

in the silt layer were not evaluated, but at other locations on similar soils rates of about 2.4 in. per hour were found.

Water table and piezometer readings from June 15 to November 8 are shown in Fig. 2. Each point is an average of three observation wells or piezometers. Rainfall is indicated at the bottom of Fig. 2 in bargraph form.

Piezometers indicated the presence of artesian pressure which increased with soil depth. Water levels in the piezometers were pumped down to the water table at the beginning of the experiment and reached equilibrium after a period of 17 days. Throughout the remainder of the experiment the 50-ft piezometers had a relatively constant water level; the 10 and 30-ft piezometers showed a decrease in hydraulic head during the season with fluctuations similar to those of the water table. The data indicate that artesian pressure is dissipated in the soil between the 10 and 30-ft depth. Therefore, the artesian pressure was secondary to rainfall in its influence on water table fluctuations.

Several rises of the water table occurred during the season, all apparently caused by rainfall. Rises in the water table took place after rains amounting to more than 1 in. on July 1, August 24, and October 28. On August 27 and September 9 rises in the 4-inch wells appeared to be a delayed response to rainfall. The curves would

indicate that 4-in. wells were more responsive at this depth. However, readings during these periods were taken only at two to three-day intervals; therefore, fluctuations, presumed more responsive in the $\frac{3}{8}$ -in. wells, did not appear.

A comparison of responsiveness of the two sizes of observation wells is shown in Fig. 3. Readings of the wells were taken a day previous to and at intervals of two readings per day for a period after a 2.08-in. rain on July 1, 1960. The largest difference in water tables as indicated by the wells, occurred on the morning of July 2. At this time the water table in the $\frac{3}{8}$ -in. wells was 5.75 ft below the ground surface, as compared to 6.11 ft below the ground surface in the 4-in. wells. The 4-in. wells lagged behind the $\frac{3}{8}$ -in. wells by 0.36 ft. On July 3, about 24 hours later, the wells indicated approximately the same water-table depth. Therefore the 4-in. wells required a period of 48 hours to reach the same water table depth as that indicated by the $\frac{3}{8}$ -in. wells.

Large-diameter wells can be expected to be less responsive than small-diameter wells owing to the relative volume of water required in each to reflect a change in water-table depth. The volume of water required to bring about an equal rise in the two wells is 114 times greater in the 4-in. well than in the $\frac{3}{8}$ -in. well. This factor plus the presence of a slowly permeable soil

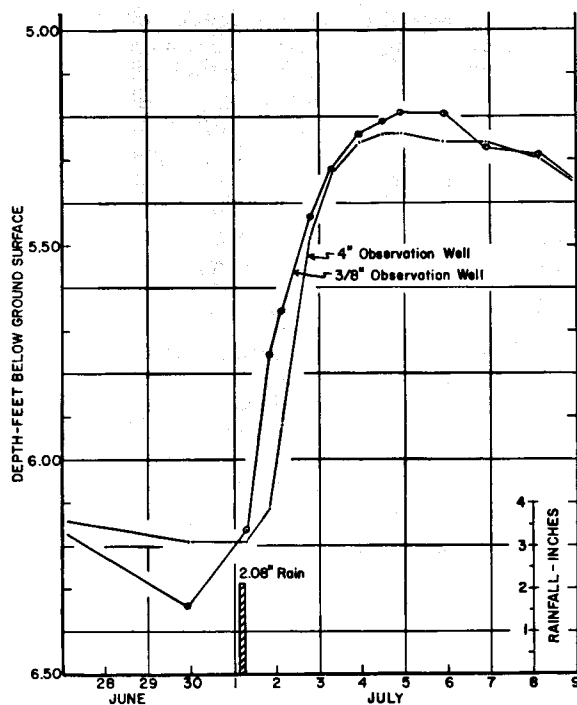


FIG. 3 Water table depths in $\frac{3}{8}$ and 4-in. diameter observation wells (average of three installations) from June 27 and July 9, 1960.

made the large-diameter wells less responsive to water-table fluctuations.

Differences in indicated water table also occurred in the absence of rainfall when the water table was receding. On June 30 and July 25 the small wells indicated a water table approximately 0.15 ft below the larger wells.

Hydraulic heads as measured by tensiometers indicated downward water flow from the ground surface on July 2. On this date hydraulic heads, above and below the water table as indicated by the tensiometers at the 5, 6, 7, and 8-ft depths, were approximately equal to the water table recorded by the $\frac{3}{8}$ -in. wells. An upward gradient was indicated from the 10 to 30-ft depth. On July 2 the 50-ft piezometer had not yet reached equilibrium (Fig. 2). The data indicated the $\frac{3}{8}$ -in. wells gave a more accurate reading of the true water table than the 4-in. wells. Piezometers will indicate the true water table under static conditions, but when hydraulic gradients are present piezometer water levels must be interpreted with care when used to indicate the water table.

A statistical analysis of the data obtained indicated there was a small but significant difference between the readings obtained between the two sizes of wells and that the dates X diameter interaction was significant. This was expected because the 4-in. well tends to be lower when the water table is rising and higher when the water table

is receding. Also, the variability of the 4-in. well readings was greater than that of the 3/4-in. well readings.

An evaluation was made of economics comparing the installation of small and large-diameter observation wells. The data are shown in Table 2. The time required to install a 4-in. well was 44 minutes as compared to 10 minutes for a 3/4-in. well. Total cost per well was \$7.96 for the large well and \$2.95 for the small well. Therefore, the cost of the 3/4-in. wells was about one-third the cost of the 4-in. wells.

Summary and Conclusions

An experiment was conducted to evaluate the comparative sensitivity and costs of 3/4 and 4-in. diameter shallow observation wells. The data showed that small wells in fine-textured soils gave a better estimate of the water table and were more responsive to influences causing fluctuations. The

TABLE 2. COMPARATIVE COSTS OF 3/4-IN. AND 4-IN. DIAMETER, 12-FT OBSERVATION WELL

Item	4-in. well		3/4-in. well	
	Time and/or material	Cost	Time and/or material	Cost
Jetting time (1-in hole)			5 min	\$0.50*
Drilling time (6-in hole)	24 min	\$2.40		
Well installation	20 min†	2.00	5 min	0.50†
Total installation	44 min	4.40	10 min	1.00
Well casing (15 ft long)	Tar fiber	3.56	Copper	2.25
Well casing (15 ft long)			Galvanized steel	1.95
Total cost per 12 ft observation well, exclusive of jetting and drilling equipment amortization costs		7.96		2.95 (steel) 3.25 (copper)

* Based on labor cost of \$6.00 per hour (3 man-hours).

† Includes gravel packing and cost of water used (3/4-in. wells only).

small well was also more economical to install.

Both large and small diameter wells have their own peculiar advantages and disadvantages depending on the primary purpose of the well. Large diameter wells permit collection of large water samples with relative ease and also provide the opportunity to collect large soil samples for visual and/or laboratory analysis.

Observation wells should not extend

below the lowest expected elevation of the water table to minimize the influence of artesian pressures.

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